SMALL ORBITAL STEREO TRACKING CAMERA TECHNOLOGY DEVELOPMENT

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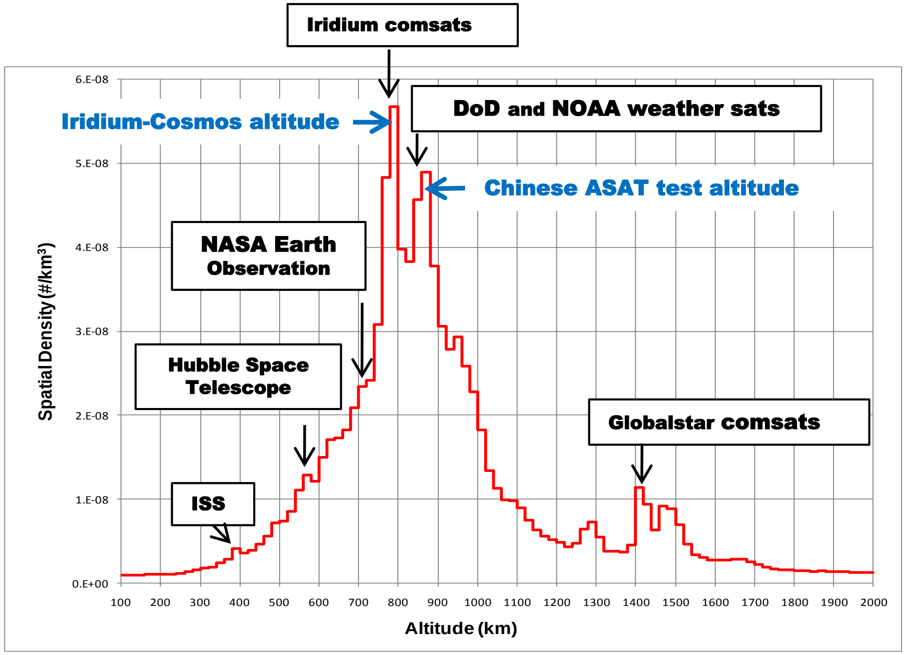
Background



Current Estimated Density of debris at various orbital attitudes with notation of recent collisions and resulting spikes (Figure curtsey of Orbital Debris Program Office: J. C. Lui)

Orbital Debris Tracking and Characterization

- Is a technical gap in the current National Space Situational Awareness necessary to safeguard orbital assets and crews due to the risk of Orbital Debris damage to ISS & Exploration vehicles.
- Added to NASA Office of Chief Technologist's Technology Development Roadmap in Technology Area 5 (TA5) [Communications & Tracking]
- Any exploration vehicle assembled in LEO must pass through this debris cloud and survive with heavy MMOD shields or alternative orbital trajectories.
- Large cross section, low thrust vehicles (such as SEP) will spend more time spiraling out through the cloud and will suffer more impacts.

The Problem: Traditional orbital trackers looking for small, dim orbital derelicts and debris typically will stare at the stars and let any reflected light off the debris integrate in the imager for seconds, thus creating a streak across the image.

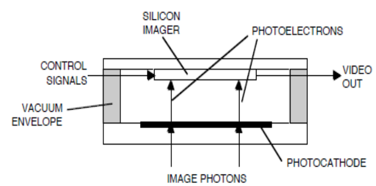
A Solution: Small, sensitive "smart" camera trackers staring along the orbital velocity, picking out non-celestial objects with proven on-board real-time processing and reporting their vectors. Pairs of these cameras as secondary payloads provide stereo range/speed via concise data.

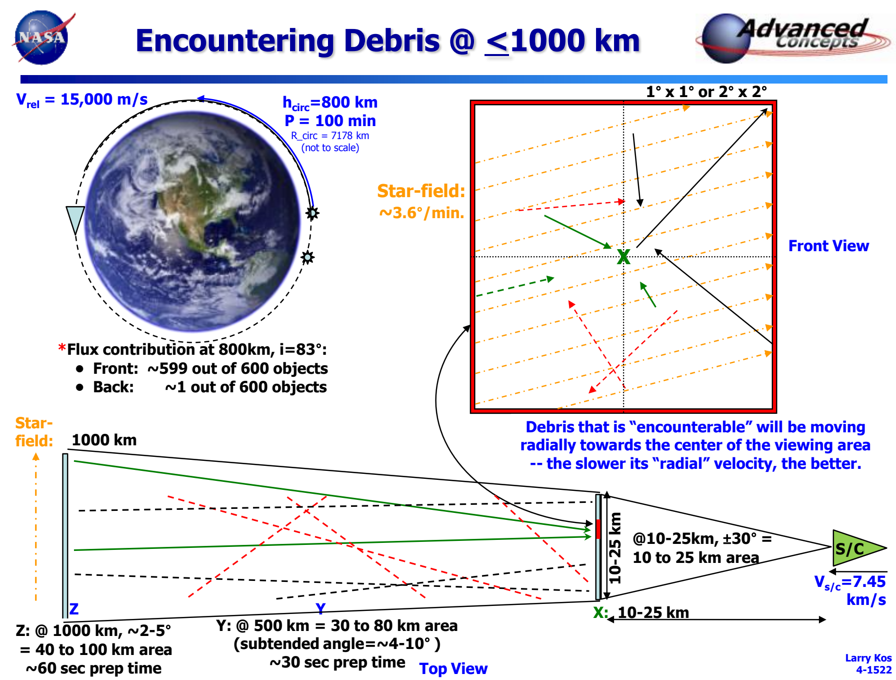
TECHNOLOGY DEVELOPMENT

<u>Small Tracker:</u>

- Will see Stars and other celestial objects “rise” through its Field of View (FOV) at the rotational rate of its orbit
- The glint off of orbital objects will move through the FOV at different rates and directions. Debris on a head-on collision course (or close) will stay in the FOV at ~14 Km per second.

An EBAPS Camera sensor amplifies their light with an intensified video imager (as found in Apache helicopters). For our purposes, we will focus our image to a narrow field of view with a telephoto camera lens that has been ruggedized for launch and outer-space use.





Conceptual images from the Small Tracker using Amplified Real-time Imaging (STARING)

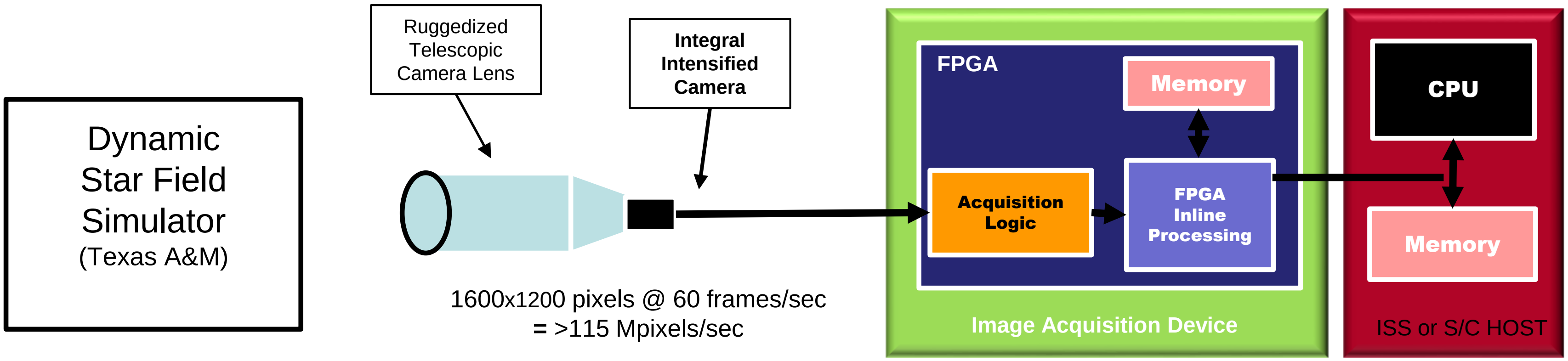
<u>Data Processing</u>:

- Uses a FPGA to convert all lit pixels to spots and identifies the spots <u>NOT</u> moving with the Stars in real-time.
- Tracking data only includes only bearing, size, and brightness of those non-celestial objects and reference star data down for ground processing

The Small Tracker tracking at 60 frames/sec allows 30 fixes before a near-miss pass. Stereo pair of Small Trackers can provide range data within 5-7 kilometers for better orbital measurements.

<u>Ground Processing</u>: Knowing the orbit of the host vehicle from on-orbit GNSS data, the few dozen snapshots of approaching orbital debris can be correlated with the reference star locations to calculate the trajectory of observed orbital object.

Small Tracker Amplified Real-time Imagining (STARING) Sensor Proof of Concept Testing



Proof of Concept tests

- Dynamic Star Field Simulator - generate a high resolution image of the background stars in motion and one to three small orbital objects to verify the control and performance of the amplified imager, pixel-to-spot FPGA processing, the orbital object discrimination algorithms and tracker pitch angle for optimal debris detection & tracking.
- Other tests - will mount the Small Tracker to MSFC's Lunar Impact Telescope Observatory to verify real-time star-field processing (similar to current Cubesat Star Tracker testing) and stereo tracker misalignments will be tested with ground processing to minimize system constrainsts.

Proto-flight Design & Testing

- Additional proton testing of the intensified imager chip and FPGA controller with pixel & spot processing will be required before designing, building, and testing the small tracker for Low Earth Orbit testing and missions using knowledge from Shuttle, DART, Orbital Express, and ISS experimental sensors.

Small Tracker Amplified Real-time Imagining (STARING)
On-Orbital Testing and Integration

Initial On-Orbit Testing – ISS

- A stationary mount with simple power and a low rate data interface with data processing on the ground
- Staring into the velocity vector is the most advantageous vantage point, however, other directions may yield good operational experience and some other tracking data.
- Single small trackers can gather valuable data as well if a stereo pair cannot be flown or one unit fails
- Visiting Vehicles coming into Station for docking and berthing can also be tracked during approach and departure operations. Data generated will enhance the MMOD environmental data for ISS orbit.

Host Vehicle Integration

- Mount a pair of units roughly parallel, provide power and a simple low speed data link for ground commands and data downlink of the orbital object spot data and reference stars
    - Would provide dozens of tracking snapshots per day
- Orbital Tracking data from Low Earth Orbit vehicles will be incorporated into the NASA Debris Density Models and can be correlated with ground based observations.
    - This approach is analogous to the NASA-MSFC Ground based Meteor Tracking Camera Network composed of many trio of simple cameras collecting data every night and processed once a day to collect time, direction, and speed of meteorites or orbital debris observed entering our atmosphere.